

Approach for Analyzing Technological Capabilities in Latecomer Software Companies

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1. Introduction

In the last two decades a group of studies has been emphasizing that the information technologies (ITs) present a ‘window of opportunities’ for latecomer countries to catch-up by developing indigenous software industries (Soete, 1985; Steinmueller, 2001). It has been observed that the availability of skilful human capital creates a base for the development of an IT industry by latecomer countries. The software industry is, in principle, a low-capital but knowledge and skill-intensive industry, and the international market for software is big and growing (OECD, 2004; Steinmueller, 2004). For this reason, the discussion about developing indigenous software industries in the latecomer context has gained particular attention both in academic and policy literature for more than a decade (Schware, 1989, 1992; Soete, 1985; Steinmueller, 2001; UNIDO, 1988).

However, developing a software industry in a latecomer or less-advanced context is not a straightforward task. To be successful and sustainable in time the development of the industry needs to involve accumulation of technological capabilities needed to enter into global markets for products and services as well as provide the basis for domestic growth and employment in software activities. Technological capabilities for software development are difficult to accumulate in a latecomer context for two main reasons. First, accumulating technological knowledge is a complex process, which requires not only acquisition of codified knowledge but also, and more so, development of tacit expertise, i.e. deeper understanding about technologies. Second, in order to build technological capabilities, the latecomers need to develop mastery over an array of highly complex skills and abilities, while the knowledge and expertise, which they possess, may be rather limited, and thus make the shift challenging, if not impossible. The success in building capabilities depends entirely on the latecomer companies’ deliberate efforts to upgrade. Although very few latecomer companies have managed to enter the international markets for software and related services, the relative success of India, China and Brazil (Arora, 2001; Athreye, 2005; Botelho, 2005; Tschang, 2005) has amplified the need to examine the contribution of technological capabilities as well as other factors to entry and development¹.

In examining the specific technological capabilities the indigenous latecomer software companies need to develop in order to be able to compete in international markets, the current literature identifies some candidates for further examination but fails to systematically address the precise nature and extent of these capabilities.

The discussion about capabilities building can be traced back to the seminal works of Schware (1989; 1992), Correa (1996) and Heeks (2002), which were discussing the entry strategies for latecomer software industries. Despite their mention of capabilities as an important driver in this development, neither of the studies provides a specific framework for analyzing the acquisition or ‘upgrading’ of capabilities in a latecomer software industry.

In research on indigenous software companies in India, China and Brazil as well as other developing countries capabilities are sometimes mentioned as an important driver, but few scholars have examined the context of technological capabilities building and few of them have attempted to provide analytical framework for investigating capabilities in the context of latecomer development, (for studies on a number of developing countries, see (Arora, 2005; Carmel, 2003; Heeks, 2002; Minevich, 2005), for India (Arora, 2001; Athreye, 2005; Tschang, 2001), for China (Tschang, 2005), for China vs. India (Contractor, 2004; Tschang, 2003), and for Brazil (Botelho, 2005). Even among those who did so, there are significant gaps, as the review in section 3 reveals.

This paper develops an approach for analyzing technological capabilities in a latecomer software industry, taking into account the specifics not only of the latecomer context, but also of the nature of software capabilities. The proposed approach identifies and disentangles a wide array of technical and organizational capabilities, which the latecomer software companies need to build, if they are to develop internationally competitive software industries based on indigenous resources. The paper also contributes to the field of technological development in the latecomer context by developing a systematic approach for analysing the array of organizational capabilities associated with technological capabilities building.

The paper is structured as follows. The following section 2 makes an overview of the concept of technological capabilities building. Section 3 presents the specifics in analyzing the technological capabilities in the software industry. Section 4 examines systematically the technological capabilities, which the latecomer software companies need to develop. The final section 5 draws conclusions and policy implications and outlines directions for further research.

2. The concept of technological capabilities building

A number of scholars agree that, to be successful and sustainable over time, technological development in a latecomer or less-advanced context needs to involve technological capabilities building (Bell, 1993; Ernst, 1998; Hobday, 1995; Kim, 2000; Lall, 1992). Technological capabilities building involve a deliberate process of learning and technology upgrading by the latecomer companies directed at the accumulation of knowledge and skills and their commercial application.

Technological capabilities can be further defined as encompassing “the great variety of knowledge and skills which firms need so that they can acquire, assimilate, use, adapt, change and create technology.... (Ernst, *et al*, 1998, p. 17). Ernst notes that this is “a broad definition, which goes beyond engineering and technical know-how and includes organizational know-how” (ibid).

From a research perspective, perhaps the greatest challenge in analysing the technological capability is that it is non-observable. Unlike R&D expenditure, the purchase of technologies or the hiring of skilled personnel, for example, it is difficult to measure and assess technological capability. In their attempts to overcome this limitation, scholars have begun to develop taxonomies of technological capabilities².

The early studies about technological capabilities were focusing predominantly on the acquisition of capabilities or expertise that latecomers need to master directly new

technologies, and these were classified as production, linkage and investment capabilities (Bell, 1993; Lall, 1992), or as production, linkage and innovation capabilities (Westphal, 1985). One of the latest studies (Ernst, 1998) explicitly emphasizes that organizational capabilities are integral elements of the technological capabilities (see the definition above). Despite these useful elements, the taxonomy of technological capabilities, which scholars have proposed, namely production, investment, and minor and major change capabilities, is somewhat generic and largely similar to more general studies of technological development process. The inclusion of two organizational capabilities, the capability for strategic thinking and the linkage capability is similarly useful, but falls short of a sufficient elaboration of technological capabilities to make a sufficiently detailed account of the role of the organizational capabilities to have much practical value.

Somewhat more useful has been the emphasis on learning as a critical driver in the process of technological capabilities building (Bell, 1993; Ernst, 1998; Hobday, 1995; Kim, 1997; 1999; Kim, 2000; Marcelle, 2004). The ability to learn is in essence an organizational capability, as it is shaped by company's attitude towards new ideas, and the openness, flexibility and aptitude to accommodate them.

This emphasis on organizational issues distinguishes the more recent studies above from earlier studies, where learning was portrayed predominantly in terms of acquisition of technical expertise. However, it is also important for latecomers to develop organizational skills - managing new technologies is not only about expertise in understanding their nature and requirements, but it also requires substantial organizational abilities to manage the application of this expertise. It is in this sense that organizational capabilities can be seen as critical drivers in the process of accumulation of technological knowledge, as they introduce the dynamics of the underlying learning process. Therefore, studies need to scrutinize how the learning process operates if they are to provide a coherent framework for analyzing technological capabilities building in a latecomer context.

The requirements of learning are related to the new emphasis on organizational capabilities such as linkage capabilities and capabilities for strategic thinking for example. Authors have suggested that, to become successful, latecomers need to be open and flexible and possess certain organizational skills (Bell and Pavitt, 1993). This has become more explicit in the latest studies which emphasize that it is exactly the deployment of organizational capabilities, like open organizational structures, active communication within and with external sources (Ernst, *et al*, 1998) expeditious learning and crisis construction (Kim, 1997), integrative learning efforts (Marcelle, 2004), organizational arrangements facilitating active knowledge management (Kim and Nelson, 2000), that lay the underpinning of successful technological upgrade in latecomer companies. Other studies (Dutrenit, 2000) have revealed that the absence of and difficulties in building organizational capabilities in latecomer context undermine the process of technological building. However, a full account of organizational capabilities, which the latecomer companies need to master, is still absent in the literature.

Building upon the existing research, this paper makes an attempt to provide more detailed account of the organizational capabilities, alongside the technical capabilities, which the latecomer companies need to develop to be able to master new

technologies. Although the proposed framework refers to the software industry, the outlined organizational capabilities can be adapted to other latecomer industries.

The principle ideas, which provide the basis for this paper's examination of capabilities building are 1) that capabilities are gained incrementally, 2) that there are a limited number of 'sequences' by which capabilities might be build, and 3) that there are important thresholds in the process of capabilities accumulation. The last of these ideas is particularly important. It is not only the capabilities to acquire and use new technologies that must be constructed, but also, and more importantly, the capabilities to generate innovation to a certain degree – from generation of incremental change and modification in acquired technologies to introducing new technologies (Bell, 1993; Ernst, 1998; Figueiredo, 2001; Hobday, 2000; Marcelle, 2004). Studies (Bell, 1993; Figueiredo, 2001; Hobday, 2000; Kim, 1997) have emphasized that it is crucial to distinguish between production and innovative capabilities, as these reflect completely different set of accumulated skills by the latecomer companies. Developing production capabilities involve accumulating skills and abilities to operate new technologies, while building innovative capabilities is a far more cumbersome task. To build innovative capabilities the latecomers need to deepen their knowledge and understanding about the new technologies to the extent that they will be able to change and modify the new technologies, and eventually to introduce new technologies.

The incremental and sequential building of technological capabilities is by no means a passive, mechanistic or automatic process. Rather, it is a deliberate process of learning and accumulation of various knowledge and skills, and their combination, in attempt to develop mastery over the new technologies (Bell, 1993; Ernst, 1998; Hobday, 1995, 2000; Kim, 1997). The initiation of a process of technological capabilities building comes as a result of a deliberate learning effort by the latecomer companies aimed at technological upgrading. Building upon a foundation of production experience, a further set of skills and capabilities are required for companies to embark on a technological capabilities building trajectory.

A particularly useful study by Figueiredo (2001) focuses on the transition from production to innovative capabilities. It disaggregated routine production capabilities and innovative capabilities, and identified the intermediate capabilities within them. The underlying idea behind this model is the sequence in building innovative capabilities, and the cumbersome transition from routine production capabilities towards accumulating innovative capabilities.

In partial summary, the requirements for a framework of capabilities building are that it needs to consider the incremental and sequential nature of technological capabilities acquisition and to recognize that there is an important threshold between 'operating' a technology and making significant adaptations and changes in the technology, which require an innovative capability that is an important threshold in the capabilities acquisition process. To these inherent features of the capabilities accumulation process, it is also necessary to add specific features related to the latecomer context and to the context of the software industry.

Latecomer companies face difficulties in crossing the threshold of developing innovation capabilities for a couple of reasons. First, being distant from lead-users,

the latecomers do not have access to information and knowledge about the latest technological developments or the precise evolution of user requirements. Second, demand within the latecomer domestic market is less sophisticated technologically than the demand in the lead markets, which makes it difficult for the domestic market to become a training ground for technological capabilities building, which might subsequently be deployed in international markets. Third, the domestic research and education infrastructure often does not provide the latecomers with suitably-trained graduates; gaps may exist in both practical management and in information and knowledge about frontier technological developments. All these make the process of technological capabilities building a cumbersome task for the latecomer companies.

Exploring the technological capabilities in a latecomer software industry presents another challenge. So far, studies analyzing the process of technological capabilities have been predominantly focused on the industrial sector, studying development of the electronics industry (Gee, 1998; Hobday, 1995; Kim, 1997; Mytelka, 1998), textiles (Gee, 1998; Lall, 1987), pulp and paper industry (Figueiredo, 2001), steel industry (Dutrenit, 2000; Lall, 1987), telecommunications (Marcelle, 2004), etc. In addition to that, very few studies have been exploring the development of a latecomer software industry, placing capabilities as a point of the analysis (Athreye, 2005; Heeks, 1998; Tschang, 2001, 2003). Their contributions and shortcomings are outlined below, as well as the fact that so far, the concept of the technological capabilities building has not been applied to the software industry, which is the aim of this paper. As the predominant part of the studies have been directed at exploring technological capabilities in industrial sector, the analytical framework developed in the field so far has been reflecting the specifics of the industrial sector. However, to be able to provide a coherent account, a study investigating the technological capabilities in a latecomer software industry needs to take into account the specifics of the software industry, which is discussed in the following section.

3. Specifics in analyzing technological capabilities in the software industry

A study about the technological capabilities building in the software industry needs to reflect the specific characteristics of the industry. First, software production, more than any other industrial activity, is almost by definition an innovation activity because it aims to produce new products or new ways of executing known tasks and functions (Torrise, 1998). Therefore, when analyzing the technological capabilities in the software industry, the distinction between production capabilities and capabilities to innovate becomes blurred. To produce software solutions latecomer companies must possess some capabilities to innovate. The significance of novelty, which governs the *extent* of innovative capability needed, varies among different software projects and is discussed later.

Second, the degree of innovativeness depends on companies' abilities, but also on customers' requirements. If a latecomer software company operates in a market with less sophisticated technological demand, it may produce software solutions, which are innovative for that market, but behind the frontier technological developments in international markets. Hence, accepting the inherent innovative nature of the software production, it is also meaningful to distinguish between innovation for international markets and innovation for the domestic market, especially when the latter is a latecomer context.

Third, the software industry is a human capital-intensive industry, rather than a physical capital-intensive industry. Development of successful software products or services depends on the deployment of skills and capabilities of the computer engineers. The challenge, which the latecomer software companies face, is to build technological capabilities enabling them to produce software, which can be commercialized abroad, based on the skills and abilities, which computer engineers have acquired in a latecomer context.

Due to the specifics of the software production, we need to scrutinize each of the constituent capabilities in the set of the technological capabilities. The development of a software industry has gained a particular attention in the literature recently, due to the spectacular outbursts of software development activities in a number of latecomers. Some analyzes have mentioned capabilities as an important driver in the latecomer software industries development, but none of them had provided an analytical framework of how to analyze them. Review of the main studies about development of latecomer software industries is done below, outlining their contributions and shortcomings.

The seminal works of Schware (1989; 1992), Correa (1996) and Heeks (2002) have outlined capabilities as a critical factor enabling latecomer software companies to enter international markets. Some of the recent studies investigating the remarkable outbreaks of indigenous software development activities in a number of developing countries, like India, China and Brazil (see for example among many others, for all developing countries (Arora, 2005; Carmel, 2003; Minevich, 2005), for India (Arora, 2001; Athreye, 2005), for China (Tschang, 2005), for China vs. India (Contractor, 2004), for Brazil (Botelho, 2005) also have mentioned capabilities as an important driver in the latecomer software industries development. But none of the above studies had provided an analytical framework of how to analyze the capabilities.

Attempts to provide a framework for analyzing the capabilities, which the latecomer software companies need to develop, have been done by Tschang (2001; 2003) and by Heeks (1998). Although these papers introduce the problem, they have significant limitations.

In discussing the development of the Rumanian software industry Heeks (1998) employs a theoretical framework based upon technological capabilities building and provides a taxonomy of the software technological capabilities. The study outlines different software production activities representing different phases in climbing the technological ladder to perform more sophisticated software production. However, it is focused only on a range of software creating activities, rather than on the capabilities underlying these activities and no attempt is made to consider whether this array should be adjusted for the latecomer context. Further, the theoretical framework seems decoupled from the empirical section, which explores predominantly the institutional foundations (and their transformation) and briefly touches upon the development of software activities in the latecomer software industry in question, and thus does not provide a clear approach of how to apply the proposed framework.

Tschang (2001) examines capabilities in terms of a software development model. Such an approach is insufficient to provide a systematic account of the range of

capabilities, which latecomer software companies need to develop in order to compete in international markets. In Tschang (2003), the author abandons the first approach of deriving the capabilities from the software development model. Rather, it provides a list of capabilities, namely individual technical skills, process maturity, management capability, technology, revenue model and product marketing capability. Although relevant and operational, this list omits important elements. It focuses on the 'outcome' capabilities but ignores the 'enabling' capabilities, like capabilities to monitor technological development and identify potential niches, capabilities for strategic thinking, linkage capabilities, capabilities to establish dynamic organizational learning environment, etc. It is exactly the 'enabling' capabilities that enable the latecomers to gain competitive position at a first place, and also, and more so, to ensure sustaining it in time.

A recent book by Arora and Gambardella (2005) analyzes the underpinnings of the successful development of the software industries in several latecomer countries, among them India, China and Brazil. Alongside the specific developments in the individual countries, the study outlines the driving forces in the development of a software industry in a latecomer context. Capabilities emerge as an important driver underlying the success of these latecomers, as emphasized in the individual countries' chapters (see (Athreye, 2005), in particular; also (Botelho, 2005; Tschang, 2005) and in the conclusions (Arora, 2005).

Despite the explicit emphasis of their importance, the analysis does not provide a unified framework for analyzing capabilities. In the individual chapters, the analysis of capabilities is combined with the rest of the factors affecting the industry development, and it is the sources of the incubation of capabilities that remain the focal points of the analysis, rather than a detailed analysis of the capabilities themselves (with the exception of Athreye's discussed further below). A similar bias applies to the conclusions, which despite emphasizing the importance of firms' capabilities remains focused on the sources of firms' capabilities rather than on capabilities themselves (Arora, 2005). An explicit framework considering the specific elements of technological capabilities building in the latecomer context and a connection with the literature in the field of technological developments in latecomer contexts are both absent.

The study by Athreye (2005) deserves further attention. Although it does not provide an analytical framework nor does it explore the issue of technological capabilities building systematically, it does capture and portray the underlying idea of capabilities building. Exploring the development of the Indian software industry and the success factors contributing to its development, Athreye (2005) observes that the evolutionary development of capabilities underpins the Indian success. Through an excellent review and analysis of development of the Indian software industry, the study reveals that the Indian companies had entered the international markets by providing basic programming skills, but over time they have developed specialised expertise and in few cases domain expertise. Further, the study emphasizes that it is the dynamic organizational capabilities, which the companies had developed over time, like the shift from on-site to offshore business model, organizational capabilities in human resource and organizational practices, large-scale projects management, etc. that ensured the Indian success in international markets.

A range of paths, including outsourcing or developing own products and services for domestic or international markets, lay before latecomers. Athreye's focus on outsourcing software products and services is just one of these paths. In the case of outsourcing for international markets, capabilities building would be heavily influenced by learning spillovers from multinational enterprises. Different paths may well require and call upon different capabilities, which latecomer companies need to master. For example, outsourcing will require a set of skills, which will be limited and significantly narrower than the set of skills required for companies to produce their own products and services.

Furthermore, the Indian outsourcing model is a specific example, as the Indian success lies on 'the winning combination of particular organizational capabilities and new business models that differentiate Indian software firms from other software providers in the global marketplace' (Athreye, 2005, p. 36). Therefore, the more general question of what kind of capabilities the latecomer software companies need to muster in order to become competitive in international markets on the basis of indigenous resources remain to a great extent open.

Torrise (1998) investigates the capabilities that software companies need to master. However, this study analyzes the Western European software industry, and thus, explores a software industry in a developed countries context. As underlined above, development of a latecomer software industry is rather different from that in developed countries context. To develop successfully, latecomer companies need to compensate for the environment, in which they are embedded in, and to do so, they need to put deliberate efforts in developing an array of technological capabilities, starting from the basic technical capabilities.

In analyzing the capabilities, which European software companies possess, Torrise has outlined five capabilities: capabilities in mathematics, computer science, system engineering, experience with application server, and marketing (Torrise, 1998, p. 136). However, if we are to explore in-depth the technological capabilities of latecomer software companies, this list of technological capabilities is rather limited for two of reasons. First, Torrise seems to assume that the basic technical capabilities are sufficient to ensure competitive performance. Thus, it omits important technical capabilities, which companies need to master to be able to produce software products and services, like for example, capabilities to develop specialised expertise in a particular domain, capabilities to diversify the products and services offered, etc. In this sense, Torrise's list is limited and does not exhaust the capabilities associated with software production, neither in a latecomer context nor in advanced context. Second, if they are to become successful, the latecomer software companies in particular need to develop mastery over a wide array of organizational capabilities, which go well beyond the single organizational capability listed by Torrise, marketing capability.

The following section attempts to fill the gaps and complete the analysis begun by the authors discussed in this section, with a particular focus on analysis and attempt to identify the technological capabilities, which latecomer software companies need to develop.

4. Approach for analyzing technological capabilities in a latecomer software industry

To be able to produce software products or services, a latecomer company needs to develop an array of capabilities. Table 1 below summarizes the technical and organizational capabilities constituting integral parts of the technological capability, which the latecomer software companies need to develop. The subsequent sub-sections examine the two sets of capabilities, technical and organizational, and within these sub-sections each of the listed capabilities is briefly discussed.

Table 1
Technological capability for latecomer software companies

Technical capabilities

Basic

Capabilities for software design

Capabilities for software programming

Intermediate

Capabilities in various operating environments

Capabilities for network applications

Capabilities for high quality assurance

Advanced

Capabilities to develop specialised expertise in a particular domain

Capabilities to diversify the products and services offered

Capabilities for introducing minor, moderate and major innovation

Organizational capabilities

Establishment of organizational culture facilitating learning

Capabilities for effective management

Capabilities for prompt delivery

Capabilities to manage small and large projects

Linkage capabilities

Marketing capabilities

Capabilities to monitor technical change and to identify niches for potential developments

Capabilities for strategic thinking

4.1. Technical capabilities

The technical capabilities discussion is organised by a classification of technical capabilities as basic, intermediate and advanced.

The capabilities, which constitute the minimal core technical capabilities, which any software company needs to possess in order to undertake software development activities, are classified as basic technical capabilities. The first basic technical capability, which the latecomer software companies need to develop, is the capability for software design. It is associated with the phase of inception of software development, when software companies need to design how the software will look and perform based on identified clients' needs. To develop expertise in software design the latecomer software companies need to develop understanding about the design of system architectures. They need to be able to design an architecture that

reflects and balances the different needs of user stakeholders; to identify the architecturally significant aspects of design, including frequently overlooked areas such as performance, resilience, and location; to use perspectives to ensure that their architecture exhibits important qualities such as performance, scalability, and security. Alongside these, the latecomers need to develop deeper understanding about design techniques, which involves building knowledge and expertise about graphics design, website design, multimedia solutions, etc. All these illustrate the range of capabilities and skills, associated with software design, which latecomers need to develop.

The second basic technical capability, the capability for software programming, is associated with the next phase in the production of a software product or service, which is the actual writing of the software. Knowledge about software programming languages and techniques, and platforms creates the base for actual writing of the software. However, latecomers need to develop deep understanding about software programming. They need to build expertise about algorithms, software programming languages, etc. Building expertise in scripting languages for WWW data (e.g. Java, XML, JavaScript, HTML, CSS, XSL, XSLT, C++, C and Object-C) requires developing understanding about their comparative utility for specific application contexts. Further, mastering one of these languages requires developing deeper understanding about it. For example, to develop excellent programming skills the latecomers need not only to learn the syntax of the Java programming language, but also object-oriented programming with the Java programming language; creating graphical user interfaces (GUI), exceptions, file input/output (I/O), threads and networking. The capabilities for software programming include expertise in system analysis. The purpose of system analysis is to produce a list of functionalities that the system should provide, to describe the functions that the system should perform, and to specify the business logic underlying the processing of data, including analysing what data is to be stored and used by the system, and how the user interface should work. To develop capabilities for system analysis the latecomers companies need to develop deep understanding about different platforms, functionality, user interfaces, and to also achieve a good understanding of the underlying business processes, which the software solution is meant to support.

The basic technical capabilities alone are insufficient for a software company to establish itself, and they need to be augmented further with intermediate technical capabilities for the latecomers to be able to perform adequately technical tasks and to become competitive.

Alongside building capabilities for software design and programming, the latecomer software companies may need also to build capabilities in various operating environments, to be able of responding to various clients' needs and requirements. Although Windows operating system is the dominant computer platform, other operating systems like Linux, Unix and Mac are also used. Therefore, the latecomer software companies need to be aware that opting for learning software design, programming and networking only on the dominant platform instead of building expertise in all existing platforms may involve costs or lost business. This type of business loss is not necessarily fatal and can be perceived as an incentive for companies to broaden their expertise by learning to undertake software activities also in other platforms, to be able to better respond to customers' requirements.

Creating a modern software product or service very often requires capabilities for networking applications. The networking applications include any kind of software solution, which operates in a network environment. A wide range of software solutions nowadays involve networking. For example, the information system in a company represents a network (i.e. intranet). Simultaneously, the companies are using software solutions operating in Internet (i.e. web-based solutions), while executing their every day operations for document sharing, coordination, communication, payment, etc. Therefore, the software company, which develops a new software solution for a client, needs to take into account the access by multiple users to the network resources such as files and to ensure security over the access as well as dealing with the need for 'file locking' to prevent simultaneous editing by different users of the same data. To be able to develop reliable networking applications the latecomer software companies need to build expertise in security engineering. They need to develop understanding about the network operating systems, security protocols, techniques for specifying and implementing a security policy, etc. This may present a cumbersome task for the latecomers, as network security is among the most dynamic fields, which has been rapidly developing recently.

Applying all of the above capabilities, the latecomer companies need to deliver high quality products and services, if they are to be successful. In order to deliver high quality products and services, latecomers need to build capabilities for software quality assurance, the last of the intermediate capabilities, in which reliability is the central issue. Developing capabilities for software quality assurance is a focus of attention among practitioners and academics, and has resulted in creation of quality assurance guidelines, reflected both in ISO certification scheme and the Capability Maturity Model (CMM) assessment scheme. Whether certified under one of these schemes, or not, latecomer software companies need to apply software quality assurance techniques to insure the quality and reliability of the software they deliver. Rigorous testing, de-bugging and defect elimination are critical steps in insuring the quality of the produced software.

If latecomer companies are to climb the technological ladder, they need to develop advanced technical capabilities allowing them to manage their knowledge base, and to combine and re-combine their accumulated expertise.

The first of the 'advanced' technical capabilities that is vital for latecomers to establish is specialised expertise and depth of understanding in a particular domain. Developing a deep understanding and expertise about frontier technologies is particularly challenging for latecomer companies as they are embedded in a latecomer context, as mentioned above, and therefore, developing expertise by focussing on a particular domain appears to be a more realistic strategy for the latecomer companies to secure their attempts for technological upgrading.

For instance, good knowledge and understanding of finance and banking system is required, if a software company is to create finance or banking software solution. The task becomes even more daunting, if a latecomer company seeks to develop finance or banking solution for international markets, where operations are far more complex and sophisticated; and therefore, the latecomer company needs to put deliberate efforts to develop deeper understanding about its specifics. A second example is the development of ERP systems. To be able to build an ERP system, a latecomer

software company needs to develop an understanding about not only the structure of the ERP systems but also knowledge and understanding of corporate practices in a particular market and a particular industry in which the system is to be employed.

The capability to diversify their products and services (the second of the advanced technical capabilities) is perhaps the most difficult to achieve by latecomer software companies. The software companies are specialised suppliers according to Pavitt's (1984) taxonomy, i.e. companies providing specialised products. Being specialised suppliers does not preclude diversification. Companies can diversify their products and services within their specialised niche. Diversifying the range of products and services, which a company offers, creates an opportunity for companies in lead economies to reap greater benefit from their knowledge base by reusing it in different contexts. The same holds for the prospects of latecomer companies to reap greater benefits by diversifying the range of their products and services. At the same time, it remains much harder for latecomer companies to succeed in diversification, due to the limited access to frontier technological knowledge and knowledge of the application domain in other countries they have, being embedded in a latecomer environment. Once the latecomer companies have developed expertise in a particular domain, they may decide to broaden the range of products and services they offer, based on the experience and knowledge they have, or market opportunities they perceive.

The degree of diversification may vary. Diversifying by introducing new products or services, which require the latecomer company to enter a new domain, which is completely separate from the domain in which the company has accumulated expertise so far is associated with high risk for any company, especially latecomers. Diversifying by introducing new products or services, which are close to the existing range, and to the already accumulated expertise in a particular field, is far less risky endeavor for companies, especially when they are latecomers. For example, developing a modular web-based platform for automated billing, invoicing and customer management for the one spectrum of services, for example Voice-over-IP involves lower technological efforts and leads to lower degree of diversification in a company which has previously developed a modular web-based platform for automated billing, invoicing and customer managements for a spectrum of services like Internet, triple play, WiMAX and regular voice communication services. Introducing systems able to address all of these applications will require significantly higher technological efforts and will result in a higher degree of diversification for a company than simply developing an automated billing application for one application. Such diversification may, however, be necessary to provide a competitive offering to those being offered by rivals. This sort of diversification is a difficult task for latecomers, given that they need to maintain the depth of expertise in a particular domain and, at the same time, to broaden the range of the products and services within that domain and, perhaps, also to broaden the expertise in different domains.

Last, but perhaps the most important of the 'advanced' technical capabilities, are the capabilities for introducing minor, moderate or major innovation. The extent to which a latecomer company has been able to accumulate a variety of skills and abilities to master new technologies reflects on its innovative capabilities, its capacity to combine, re-combine and deploy its expertise.

As underlined above, innovativeness is an intrinsic characteristic of the software

production and yet the degree of innovativeness may vary. This point is particularly important in studying the latecomer software industry, as it requires the research to disentangle the software innovation process and to classify the software production in terms of its degree of innovativeness. So far this has not been done for software production in the latecomer context and the following analysis attempts to address this point.

The innovative component is inherent to the very nature of software production, as outlined by Torrisi (1998). However, different types of software production activities involve different level of innovative efforts and respectively, result in software products and services with different degree of innovativeness inbuilt in them. Software services like re-coding legacy applications into more modern computer languages, data migration, or resolving specific incompatibilities between similar systems, etc, involve a relatively small innovative component. On the other hand, producing software customized services and software packages usually involve higher degree of innovativeness. For example, to successfully launch an ERP or CRM system, or e-commerce solution, a latecomer software company needs to deploy sophisticated knowledge and expertise, and to offer a solution, which is comparable to the frontier technological developments in that particular domain. Therefore, it is meaningful to distinguish between capabilities for minor, moderate and major innovation, when studying the degree of innovative efforts associated with producing particular software products or services.

The proportion of activities like re-coding, data migration, resolving incompatibility, etc. can be expected to account for a significant share in the software services offered by latecomer companies. On the other hand, the presence of major innovative activities, like creation of packages or customized services, despite their small share in the latecomer software developments, signals the existence of potentially significant innovative capabilities in the latecomers. This makes it important to analyze the type of software activities which the latecomer companies offer, and the type of innovative capabilities (i.e. degree of innovativeness) they involve.

As the capability for minor, moderate and major innovation reflects the level of technological maturity, which the company has achieved, it is classified as advanced technical capability. This does not imply that it develops last among all capabilities. On the contrary, it emerges with application of the basic technical capabilities (due to the innovative nature of every software activity) and deepens further alongside development of the rest of technical capabilities. As it affects the way the rest of the technical capabilities are mobilized, its level of development does reflect the level of technological sophistication of the company and for this reason it can be treated as advanced technical capability.

4.2. Organizational capabilities

As outlined in section 2, the development of organizational capabilities is particularly important in the process of technological capabilities building by the latecomers. The proposed approach makes an attempt to outline a set of organizational capabilities, which the latecomer companies need to develop, and although these are applied to the case of the software industry, they can be easily adapted to any other latecomer industry. As the approach aims to outline the organizational capabilities in latecomer companies, it identifies and classifies the capabilities taking into account the specifics

of the latecomer context. It bears an element of idiosyncrasy, as although it uses ideas from management literature, it adopts them to the specifics of the latecomer context. It deliberately disentangles the organizational capabilities reaching a low level of desegregation. Further, it places emphasis even on basic organizational capabilities, like organizing, communication and control, as the latecomer companies may lack or possess limited capacity even in such basic management capabilities.

The first of the organizational capabilities, the ability to establish organizational culture facilitating learning can be considered as the most fundamental capability, as it underlines the development of all technical and organizational capabilities. The ability to learn is shaped by company's attitude towards new ideas, and the openness, flexibility and aptitude to accommodate them. Developing "learning to learn" capability can be challenging. Accumulating new information and knowledge and developing capabilities to master new technologies often requires adopting new perspectives in dealing with problems, new ideas, new ways of approaching a problem and finding a solution, and developing new ways of executing known or new tasks. It may also challenge some already established routines in the company, and require 'unlearning' and abandoning some of them. All these require openness. The latecomer companies therefore need to establish an environment for accumulation of information, exchange of ideas, and knowledge generation and re-combination. To achieve that, the whole organization needs to be 'tuned' into a learning mode, a mode which appears to require a degree of openness and exploration. Learning inevitably involves change. Adopting new ideas and developments often necessitates undergoing some sort of change. In this sense, abilities to learn are closely coupled with change management skills. Case studies of successful technological development often confirm that it was indeed the change management capabilities that underpin dynamic technological and organizational learning (Kim, 1997; 1999; Kim, 2000; Marcelle, 2004). Further research is yet to be conducted to delve into the complexity of developing organizational capabilities by the latecomers.

The abilities to establish organizational culture facilitating learning constitute essential elements of the capabilities for effective management. The former have been outlined separately, as they represent the major driver of the process of technological capabilities building. The latter, the second of the organizational capabilities, is no less important. Every single aspect of organizational functioning is affected and indeed shaped by a company's management. The vision of what and where the organization should be in the future and the strategy for pursuing it are driven by managerial decisions. Organizational processes, like communication, decision-making, coordination, control, etc. are contingent on management strategy and decisions. A company with effective management involves its members in active communication with each other, participatory decision-making and well-coordinated activities; and team building and working in a team are essential elements in the organizational culture. Establishing effective management practices can appear a difficult task for any company, but it is particularly difficult for latecomers, due to their limited business experience. Strict hierarchy and/or restrictions in communication and decision-making about routine activities and new developments may produce uneven information flows and 'gate keeping'. In its extreme form this may result in rigid organizational structures and restricted information exchange flows, and will be detrimental to learning and technological capabilities building in the company.

Overcoming organizational rigidities requires an interactive and open environment in the organization which makes it possible to be receptive to new ideas and new developments. Moving towards this pattern from the heritage of more hierarchical and controlled interaction requires change management activities. Change management activities affect company's activities in all levels: tasks performed by individuals, various organizational processes (communication, decision making, coordination, control, etc.), overall strategic vision, organizational culture, etc. In order to perform effective change management the organizations need to constantly monitor their activities and the signals by the external environment, and to undertake re-adjustments in the organization. All above illustrates the complexity, which the latecomers face in developing effective management abilities, enabling them to master the organizational and technical dynamics underpinning the development of new technologies.

The third of the organizational capabilities, which the latecomer software companies need to build, is the capability for prompt delivery. Meeting deadlines is crucial, as failure to do so result in increasing costs of project and customer dissatisfaction. Delivery on time is crucially important in international markets. In latecomer countries, where the market power of suppliers may be high or where there are high transactions costs of changing suppliers, clients might be more lenient toward delays and this creates a challenge for latecomer companies to learn to execute projects meeting strictly the deadlines. To be able to do that, they need to develop abilities and skills for project management, tracking the work progress throughout the project, clarifying project requirements at the very beginning, effective communication between parties throughout the project, etc.

To take best advantage of market opportunities, latecomers should develop project management skills to manage both small and large scale projects. Project management involves identifying the activities to be undertaken within the project, setting deadlines and creating workflow plans, assigning responsibilities, monitoring the work progress and delivering quality outcomes within the deadlines. Managing large-scale projects poses greater challenges for latecomers. The large scale projects may require resources well beyond those under the company's control, as normally the latecomer companies are small-scale and possess limited resources and sometimes even limited expertise. If a latecomer company faces the opportunity of executing a large-scale project, it has to be able to mobilise the necessary human resources and the additional expertise it may need. It also has to be able to coordinate the proliferation of tasks that large scale projects produce, a process different in degree if not in type from the process of managing smaller-scale projects. Large projects require the efficient location of knowledge and other necessary resources as well as rapid response and excellence in coordination. Developing capabilities to manage large projects appears one of the critical drivers underlining the success of the Indian software industry (Athreye, 2005). Being capable of managing large projects the latecomers are in a possession of a large pool of resources, which they are able to deploy and utilize. When these are coupled with relevant technical expertise and other organizational skills, the latecomer software companies are in a position to compete.

Establishing links and relationships with clients, suppliers and other parties, the fifth of the organizational capabilities identified, have been identified as vital capabilities for latecomer companies, as these provide channels for obtaining information and feedback on technological dynamism (Bell, 1993; Ernst, 1998; Hobday, 1995; Kim,

1997). User-producer interactions have been outlined as one of the major drivers for generating innovation (von Hippel, 2000), as the users possess in-depth understanding about the work processes, the performance of the existing technologies and potential niches for further developments. In this sense, close interactions with clients can generate ideas for modification and improvement in the existing products and services. In the case of latecomers, interactions with clients are even more important, as the latecomers, being embedded in a latecomer context, have limited information about new developments and are away from lead users (Hobday, 1995). Therefore, establishing and maintaining links and relationships with clients, foreign ones in particular, are important channels for obtaining information about new technological developments, feedback and identifying potential niches for further developments. Likewise, links with suppliers and other agents in the innovation networks (universities, research institutes, consultants, etc.) contribute significantly to the accumulation of information about new developments and the latecomer companies need to be able to tap also the potential of these sources of information.

Alongside development of the previous five organizational capabilities, latecomer companies need to develop marketing capabilities, the sixth of the organizational capabilities. The latecomer software companies need to be capable of identifying potential clients, approaching them, promoting their in-house capabilities for software developments, and maintaining relationships with their clients upon completion of the project for further developments, etc. The abilities to market in-house skills and expertise are crucial in ensuring the latecomers' success. Only successful commercial application can harness already developed technical and organizational capabilities, and allow further expansion. Developing marketing capabilities is often difficult for any company, but it is very much the case with the latecomers. The latecomer companies may possess (sometimes very) limited knowledge about the structure and functioning international markets, which prevent them from being able to identify the right approach for entering a particular market, positioning themselves in the market and identifying the right customers. Further, even if successful in all of the above and having identified the right clients, the latecomer may fail in approaching and establishing contacts with them for a variety of reasons. In the domestic market, the latecomers have access to local customers with whom they share the same cultural and business background, which makes establishment and maintaining contacts easier. This does not hold for the international customers, where the latecomers need to build relationship, taking into account international business ethics and management, and dealing with inter-cultural differences such as different norms or even beliefs. Thus, developing skills in international business management becomes one of the prerequisites for latecomers' success.

Capabilities to utilize the in-house expertise involve not only finding clients for existing products and services but also identifying niches for potential new developments. Capabilities to monitor technical change and to identify niches for potential developments are the seventh of the organizational capabilities identified in the proposed framework. They require not only marketing expertise, but also draw heavily on the accumulation of technical expertise. To become competitive and sustain its competitive position any company (and particularly a company in a high-tech sector) needs to keep abreast with the new technological developments. To achieve that, the companies need to stretch their capabilities beyond mere monitoring of technological development. They need to develop in-depth knowledge and

understanding about technological development to be able to identify potential niches for new developments. Latecomers are confronted by the challenge of building the necessary technical and organizational expertise to master the existing frontier technological developments, and some of them may well remain far behind in managing the existing frontier developments. Developing capabilities to identify potential niches for new developments require further deliberate, focused and persistent efforts to expand the technical expertise and organizational abilities, to reach a definitive level of technological mastery enabling companies to foresee trends of development and to identify niches for potential new applications. Being embedded in a context, which does not expose them to the latest technological developments, and being away from lead users, latecomers may well find this to be a difficult task.

The last of the critical organizational capabilities is strategic thinking. In their business activities the latecomer companies need to apply strategic vision of where the company is going in a longer term. The ability to think in a strategic way underpins latecomers' success. Ernst (1998) identifies it as one of the five technological capabilities which latecomers need to develop. The managers need to have a clear vision what the company is aiming to accomplish in the future so they are able to prepare and undertake the intermediate steps towards the final goal. In setting their goals the latecomer companies are to take into account their standing with respect to the development of the world industry. Questions like 'where do the products and services offered by the company position with respect to development of the world industry', 'in what direction and how the company can upgrade', etc. must be answered to achieve a sustainable position in the international market. It would be a mistake to assume that the latecomers should aim to position themselves as competing against the world players, as these may be quite unrealistic. As the Arora and Gambardella (2005) study suggests, the success in development of latecomer software industries lies in finding a niche in which the latecomers have a competitive advantage. To be able to identify an appropriate niche the latecomers have to have a deep understanding about the technological development of the world software industry and its trends, and the position, which the latecomers hold with respect to technological and organizational expertise and market strategy. Such assessment should adopt a dynamic perspective to re-assess changes over time. Once they have the vision set, the latecomers need to pursue their aim by undertaking the steps leading towards it. These would involve strategic actions like establishing partnerships, building new expertise and expanding existing knowledge, and the like.

5. Conclusions and directions for further research

This paper contributes to the existing body of literature by suggesting an approach for analyzing technological capabilities in a latecomer software industry. The proposed approach outlines and disentangles a wide array of technical and organizational capabilities, which the latecomer software companies need to build, if they are to develop internationally competitive software industries based on indigenous resources. The paper also contributes to the field of technological development in the latecomer context by developing a systematic approach for analysing the array of organizational capabilities associated with technological capabilities building.

The main propositions advanced by this paper highlight that development of indigenous latecomer software industries is a daunting task for the latecomers, as technological capabilities building is uncertain and complex process, involving

development of a number of interrelated elements (e.g. technical and organizational capabilities), which may be poorly developed individually or in their integrity in the latecomer context. By disentangling the wide variety of technical and organizational capabilities required for a latecomer software company to develop successfully, the paper improves significantly our understanding about the prerequisites for development of indigenous software industries in the latecomer context and suggests that some of the existing academic and policy views need be enriched. While discussing the possibilities for development of latecomer indigenous software industries, the studies need to take into account the wide array of technical and organizational capabilities, which the latecomer companies need to build, and the complexity of technological development in the latecomer context, and to assess the achievements and challenges in the capabilities building process. Public policies aiming to support development of latecomer indigenous software industries need to go beyond building infrastructures (telecommunication, technological infrastructure, education, etc.), and should focus on capabilities building in the latecomer companies. They should facilitate accumulation of technical capabilities but also (more so) organizational capabilities, as the latter are critical for harnessing the potential in the company and at the same time may be difficult to develop in the latecomer context.

The proposed approach opens avenues for investigation of technological capabilities and for comparison between different levels and patterns in their accumulation. One direction of research is to analyze the accumulated technological capabilities in latecomer software industries, which follow different paths of development. For example, it would be appealing to explore the accumulation of technological capabilities in a latecomer software industry, which is actively involved in outsourcing (like India, for example), and to compare these with the accumulation of technological capabilities in a latecomer software industry, which attempts to develop own software products and services (like Brazil, for example), and to investigate whether different patterns of accumulation of technological capabilities emerge. Another direction of research is to compare successful and less successful software companies in order to outline the capabilities that appear critical and those that appear difficult to develop in the process of technological capabilities building. The third direction of research is not confined only to the software industry and calls for in-depth analyses of the impact of the organizational capabilities in the process of technological capabilities building. In all of these cases, the framework offered here provides a comprehensive foundation for examining the range of capabilities required for achieving a sustainable market position – either in the process of entering into selected niches in international markets or creating the capabilities to retain an advantage in domestic markets against competition at home and from abroad.

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Notes:

¹ Very few latecomer companies have managed to enter international markets not only in software activities but also in the whole range of activities of new technology based firms, which illustrates the difficulties in building technological capabilities in new technological areas, and also influence of other entry factors and developments.

² The philosophy underlying the development of taxonomies of technological capabilities is to disentangle the constituent capabilities, which the latecomers need to develop, and in this sense it contributes to making technological capability observable to a greater extent than before. The analyses of capabilities development by following taxonomies are coupled with indicators for export intensity and patterns of penetration in international markets in order to make the analyses more robust.